HEAT EXCHANGER AND METHOD OF MANUFACTURE THEREOF

The present invention relates to a heat exchange element and a formable laminate for the manufacture of such a heat exchange element in particular for use in heat exchange between two fluid flows such as in an evaporative type heat exchanger. The invention also relates to a method of manufacturing such a heat exchange element.

Heat exchangers for heat exchange between two fluid streams are generally known in which a dividing wall separates the two fluid streams. In general, it is an objective of many such devices to increase the surface area of the dividing wall to increase the effective heat transfer between the two fluids. Generally, the wall will be thin to maximise the thermal gradient and in such cases, the conductivity of the wall material is not critical if its total area is sufficiently large. A device is known from EP0777094, which uses a corrugated sheet to produce a heat exchange element.

It has also been suggested to use metal sheet formed into U-bends to form a dividing wall. Such a device is known from US4384611. Conventional metal heat exchangers have used various techniques to join parts of the exchanger together. Typical joining techniques include crimping, welding, brazing and adhesives. The use of such techniques has been found to have certain disadvantages in terms of cost, integrity and complexity of the joint and the joining procedure. Particularly in cases where a wall is provided with additional fins to achieve the required heat transfer, the joining of the fins to the wall is difficult.

In low temperature applications such as domestic heat recovery and dew point coolers, plastics material and the like has frequently been adopted since it is relatively cheap to produce and easy to form into the desired shapes. A dew-point cooler is a particular form of evaporative heat exchanger, which attempts to bring down the temperature of a product air stream to as close to the dew point temperature as possible. For air at a given absolute humidity, the dew point is the temperature at which the air reaches a relative humidity of 100%, at which point it is saturated and can absorb no further moisture. The heat is removed from the product

air stream by evaporation of a quantity of liquid into another working air stream. Such a process is theoretically extremely efficient and requires no compressor, as is the case for conventional refrigeration cycles. Many attempts have been made to realise such cycles but practical considerations have caused great difficulties in approaching the dew point over most temperature ranges.

An indirect evaporative gas cooler is known from US4976113 to Gershuni et al. where the product and working air streams are in counter flow. Other devices are known which operate substantially in cross flow such as the device known from US2003/0033821 to Maisotsenko et al. The teachings of the present invention may thus be applied to devices according to both of the above disclosures, the contents of which are hereby incorporated by reference in their entirety.

In the following, the term dew-point cooler will be used to refer to devices that cool a fluid to at or near its initial dew point by heat transfer to cause evaporation of a liquid into a working fluid operating at or near its saturation point. Particularly in the case of dew-point coolers, it has been found desirable to use fins attached to a dividing wall to achieve the necessary heat transfer under conditions where the temperature gradient across the wall is small.

According to the present invention there is provided a heat exchange element comprising a formable laminate of a metal layer and a heat-seal layer, the laminate being sealed under heat and pressure to itself or to another similar laminate to form a flow channel for a heat exchange medium. By providing such a formable laminate, complex shapes such as convolutions, fins and the like may be easily produced that are fluid tight, ensure good heat transmission and are robust.

According to an advantageous embodiment of the invention, the metal layer comprises aluminium, in particular soft annealed aluminium, which can be easily plastically deformed. Other similar metals may also be used but soft annealed aluminium has been found particularly cheap and easy to work. In particular, by choosing a material that is relatively inelastic, deformation of the laminate is unlikely to cause separation of the heat-sealed sections. Such forces may alternatively or additionally be reduced by choosing a relatively thin metal layer in the form of a foil. Preferably the metal layer may have a thickness of between 25 microns and 120 microns, more preferably around 70 microns.

In a particular embodiment of the invention, the heat-seal layer is substantially coextensive with the metal layer and may be applied by coating onto either one or both sides of the metal layer.

Depending upon the nature and intended use of the heat exchange element, the laminate may further comprise additional layers. A layer of primer or the like may be required between the metal layer and the heat-seal layer to improve bonding or to provide protection against corrosion. Such primer may also be pigmented or otherwise coloured to improve the aesthetic effect or to optimise heat transfer. Furthermore, for use as an evaporative heat exchanger, humidifier or for improved wicking, a water-retaining or water-transporting layer may be provided over some or all of the surfaces of the laminate. This layer may be adhered by means of the heat-seal layer or otherwise.

According to a first heat exchanger construction, the laminate may be formed into a convoluted shape or corrugated to form a plurality of fins thereby providing an increased surface area. In this context, an increased surface area is understood to mean an increased surface area for a given volume.

According to an alternative heat exchanger construction the laminate may be provided on one or both surfaces with a plurality of fins or other constructions in heat conducting relationship with the laminate to increase the surface area thereof. By the advantageous use of a metal/heat-seal laminate as described above for these fins, they may also be easily connected by a combination of heat and pressure. The fins may further be provided with other surface area increasing elements or elements for breaking up the boundary layers of the fluids used. Such elements may take the form of louvres or openings in the fins.

A convenient shape for the flow channel is that of an elongate flat tube of generally rectangular cross-section. For use in a heat exchange unit, a number of such flow channels may be located side by side in a suitable housing whereby a primary fluid can flow through the tube and a secondary fluid can flow over the outside thereof. The tube may comprise a single laminate folded on itself and joined at the edges

along a single elongate seam. Alternatively, it may be formed of two halves from first and second laminate portions sealed to one another along respective edges.

According to a particularly advantageous application of the invention the flat tube comprises fin sections on both the interior and exterior surfaces of the laminate. The fin sections on the interior surfaces support against one another and help maintain the mechanical rigidity of the tube. This is a particular advantage of the construction which allows the use of such extremely thin gauge material. For use as a dew point cooler, at least the fin sections on the exterior surfaces are provided with water retaining layers. The interior of the tube may thus serve as a primary dry flow channel and the exterior of the tube may form part of the secondary wet flow channel.

The invention also relates to a method of manufacturing a heat exchanger comprising providing a plastically deformable first metal laminate; providing a plastically deformable second laminate; plastically forming the first laminate into a generally corrugated shape having a series of troughs; connecting the first laminate to the second laminate at the series of troughs to form a heat-transmitting wall with heat-conducting fins; and sealing the second laminate to itself or to another similar laminate to form a flow channel.

Preferably, either the first or the second laminate comprises a heat-sealable layer and the first and second laminates are connected together by heat-sealing at a first temperature.

Both the first and second laminates are preferably laminates as described above. In which case the second laminate may comprises a heat-sealable layer differing from the first laminate so that the second laminate can be sealed to itself or to another similar laminate by heat sealing at a second temperature lower than the first temperature. In this manner, the fins may first be connected to the second laminate prior to forming the second laminate into a flow channel.

The method may further comprise the step of dividing the first laminate into sections prior to connecting it to the second laminate. It has been found that individual fin

sections separate from one another can prevent heat conduction along the heat exchanger and can also help to encourage turbulent flow by breaking up the boundary layer. This may also be achieved by forming louvres in the first laminate prior to connecting it to the second laminate.

According to a particular embodiment of the invention, the method further comprises forming a water retaining layer on a first surface of the first laminate, wherein the second surface of the first laminate is connected to the second laminate. The heat exchange element produced in this way may ideally be used in a dew point cooler, for humidifying dry air or in a heat recovery device.

The invention also relates to a method of manufacturing a heat exchanger, comprising:

two sets of medium through-flow channels placed mutually interlaced, which sets of channels form respectively a primary medium circuit and a secondary medium circuit, through which two medium flows can flow which are physically separated and in heat-exchanging contact;

heat-conducting walls separating said channels; and

a housing in which the walls bounding the channels are accommodated, to which housing connect at least one inlet and two outlets for the two sets of channels.

The method comprises:

(a) providing a plastically deformable plate, for instance of a plastic or a metal such as copper or aluminium;

(b) providing at least one metal strip moulded into a general wave shape, for instance of copper or aluminium, which can serve as a row of fins;

(c) plastically deforming the plate such that it acquires an edge zone with which it can be connected to a similar plate;

(d) prior to or after step (c), connecting the strip to the plastically deformable plate by means of the outermost surfaces of the wave shape directed toward the strip such that a heat-conducting wall with heat-conducting fins is created;

(e) repeating steps (a), (b), (c) and (d) a number of times to obtain a number of heat-conducting walls with fins;

(f) connecting these walls at least in twos to each other using the edge zones according to step (c) such that a chosen number of such walls is placed in mutually parallel relation; and

(g) accommodating these walls in the housing.

In this way there is provided a method of manufacturing a heat exchanger which can be performed very inexpensively, rapidly and with great reliability, so that the heat exchangers can be manufactured, also in mass production, at considerably reduced cost compared to the prior art.

The plastic deformation can be carried out in any appropriate manner, wherein the choice is determined partly by the nature and type of the applied material. Use can for instance be made of pressing, thermo-forming, vacuum-forming, injection moulding.

Particularly in the important case that aluminium is applied, the method can advantageously be embodied such that the plastic deformation according to step (c) takes place in cold state.

The method can for instance be embodied such that the plate and/or the fins are provided prior to step (d) with an adhesive layer and that step (d) is performed by pressing the plate and the fins against each other at least at the position of the contact surfaces, optionally while heating.

A simple press tool can for instance be used for this purpose which provides the necessary adhesion through pressure and optional heating for a certain time. It must be ensured that the heat resistance represented by the adhesive layer lies below a predetermined value. This means that the adhesive layer, given its heat-conducting properties, may have only a limited thickness after forming of the connection.

Particular advantages are provided by the method in which the adhesive layer substantially covers the plate and/or the fins completely and protects them against corrosion. The adhesive layer hereby fulfils an adhesive and an anti-corrosive function.

The method can for instance be embodied such that the adhesive layer is applied as foil.

Particularly when a thermoplastic plastic is applied as material for the plastically deformable plate, the method can be embodied such that the adhesive layer is formed together with the plate by co-extrusion into a laminated co-extrudate.

An important variant of the method has the special feature that the plate and/or the fins consist of a material to which the adhesive layer adheres with difficulty, for instance aluminium, and that the part of the adhesive layer directed to the aluminium is adhered thereto via a layer of primer.

The primer layer provides an excellent adhesion of the adhesive layer to the aluminium. Without the primer this adhesion would leave something to be desired, which cannot be permitted in respect of the reliability of the heat exchanger.

The latter specified method can advantageously be embodied such that the primer has a chosen colour, pattern and/or texture, and that the adhesive layer is transparent. The primer can for instance be gold-coloured. A heat exchanger plate hereby acquires an extremely attractive appearance. Colour, pattern and/or texture can also serve as coding for heat exchanger components, with an eye to ready identification of the category within the selection of technical specifications.

In yet another embodiment the method has the special feature that the primer and/or the coating contain silver, such that the adhesive layer has an anti-microbial action. This embodiment has the advantage of not requiring any specific provisions in respect of for instance bacterial contamination.

According to yet another aspect of the invention, the method has the special feature that finished plates with fins are adhered to each other in alternate pairs using edge zones, and that a number of thus formed pairs are stacked onto each other prior to step (g). The finished plates or walls can for instance be identical.

The latter embodiment of the method can particularly take place such that adhesion takes place by providing the plates in advance with the adhesive layer and pressing the edge zones against each other, optionally while heating. This method can also be performed in exceptionally simple, inexpensive and rapid manner.

This latter described method can further be embodied such that the plates are adhered to each other via a sheet which is placed beforehand therebetween and which is provided on both sides with an adhesive layer, and that the respective edge zones directed toward each other and preferably also the respective outer surfaces of the fins directed toward each other are thus adhered to each other by being pressed together, optionally while applying heat, for instance by feeding through hot air.

In one embodiment of the heat exchanger, at least the fins in the secondary medium through-flow circuit are provided with a hydrophilic and porous or fibrous coating, consisting for instance of a microporous Portland cement, which layer is kept wet by watering means forming part of the heat exchanger such that, through evaporation therefrom by the secondary medium, respectively the layer, the secondary fins, the wall, the primary fins and finally the primary medium are cooled, which layer has a small thickness such that in wet state it has a sufficiently low heat resistance such that the heat exchanger can operate as dew point cooler.

In order to obtain a good mechanical strength, corrosion resistance and heat transfer in combination with relatively low cost, the heat exchanger can have the special feature that the sheet is embodied as a laminate, comprising a metal inner layer which is coated on both sides with plastic outer layers. The inner layer can for instance consist of aluminium with a thickness in the order of magnitude of 25 μm. The plastic outer layers, which can consist of any suitable plastic, can for instance also have a thickness in the order of magnitude of 25 μm or less. With such a small thickness the heat resistance represented by the plastic outer layers is negligible.

According to another aspect of the invention, the heat exchanger can have the special feature that two sheets are each folded into the form of a rectangular wave shape, wherein the two wave shapes have equal pitch, and are positioned mutually interlaced with a relative longitudinal orientation of 90°.

Embodiments of the invention will now be described by way of example only with reference to the annexed drawings, in which:

Fig. 1a shows a perspective view of a plastic sheet moulded by thermo-forming, on both sides of which heat-conducting fins are arranged;

Fig. 1b shows the phase in which the sheet is folded along the two fold lines such that the walls are moved toward each other;

Fig. 1c shows the end position in which the two walls are positioned fixedly in mutually parallel relation;

Fig. 2a, 2b and 2c show views corresponding to respectively fig. 1a, 1b and 1c of an embodiment with the same width but of greater length;

Fig. 3a shows a perspective view of a sheet having in the zone of the walls rectangular perforations for passage of fins;

Fig. 3b shows a perspective view of a heat-conducting wall, on both sides of which fins are arranged which fit into the perforations of the sheet according to Fig. 3a;

Fig. 4 shows a partly broken-away perspective view of a heat exchanger, wherein the housing is omitted for the sake of clarity;

Fig. 5a and 5b show perspective views from different sides of a dew point cooler;

Fig. 6 is a perspective view of a part of a dew point cooler;

Fig. 7 shows a view corresponding with Fig. 4 of a variant;

Fig. 8 is a cut-away perspective view of an alternative of the embodiment of Fig. 3a and 3b;

Fig. 9 shows a schematic perspective view of a heat exchanger constructed from two sheets folded in mutually interlaced manner;

Fig. 10a shows a very schematic view of a compression mould for modelling a plate into a heat-exchanging wall;

Fig. 10b shows a very schematic view of the arranging of strips of fins on either side of the wall;

Fig. 10c shows the heat-exchanging wall having heat-conducting fins arranged thereon;

Fig. 10d shows the stacking of four such walls with fins in order to form the interior of a heat exchanger according to the invention;

Fig. 11 shows an alternative, wherein the heat-exchanging walls and also fins are adhered to each other by means of an adhesive foil;

Fig. 12 is a perspective view of a practical embodiment of a strip of fins; and

Fig. 13 is a perspective view of a moulded wall.

Fig. 1 shows a moulded sheet 1 consisting of a thin foil-like material of for instance polystyrene, PVC or PET. It is possible using such materials to apply a relatively small wall thickness, for instance in the order of 0.1 mm. Inexpensive production with a short throughput time is possible with for instance thermo-forming.

Sheet 1 is provided on both sides with schematically indicated packets of fins which, in Fig. 1, are designated 2 for the primary medium through-flow circuit and 3 for the secondary medium through-flow circuit.

Attention is drawn to the fact that the fins 2, 3 are shown very schematically. They consist in this embodiment of strips of limited length moulded in zigzag form in the longitudinal direction, i.e. the medium flow direction. This aspect is however not significant for the present invention.

Deflector dams 4 are formed in sheet 1 for deflecting the relevant medium flow. This aspect will be further elucidated with reference to Fig. 4.

Sheet 1 further has a number of condensation outlets in the form of funnel-shaped structures with triangular intermediate forms 5 for draining water. This may for instance be condensation water, although in the case of operation of the heat exchanger as dew point cooler it may also be excess water added to the secondary medium circuit.

As will be apparent from comparing the three successive steps of Fig. 1a, 1b and 1c, the walls 8, 9 are folded toward each other along hinge lines 6 and 7 to form the folded-up situation shown in Fig. 1c. The construction obtained here is an element of a packet of such elements together forming a heat exchanger. Reference can for instance be made in this respect to Fig. 4, 5a, 6 and 7.

The heat exchanger can also serve for instance as a dew point cooler. As described above, an effective, for instance intermittent watering of the heat-exchanging surface in the secondary medium circuit must in that case be ensured. This implies that fins 3 must be provided with a coating which has a hydrophilic character and which exhibits an open porosity or fibrous structure such that a rapid distribution of water or other evaporable liquid can occur through capillary suction. The manner in which this watering takes place falls outside the scope of the present invention and will therefore not be discussed further. Fig. 5a shows this watering symbolically.

During this production phase, in which the fins are already arranged, sheet 1 according to Fig. 1a is treated by at least wetting the fins, in any case on their outer side, and by then applying a mortar in powder form to the fins by atomisation. The thus obtained coating of microporous Portland cement can have a thickness in the order of for instance 50 μm. The process in question is highly controllable and produces a hydrophilic and water-buffering coating. The fins 2 in the primary circuit are not provided with such a coating, since no evaporation occurs in the primary circuit.

The free edges 10 of wall parts 8, 9 are carried toward each other as according to Fig. 1b and connected to each other as according to Fig. 1c, for instance by glueing, welding or the like. It will be apparent that a sealing primary medium channel is obtained in this manner. For sealing of a secondary medium channel in which the fins 3 extend other provisions are necessary, in particular sealing means co-acting with a housing.

Fig. 2a, 2b and 2c show structures the same as those according to Fig. 1a, 1b and 1c, with the understanding that the length in the medium flow direction is greater. It is noted here that the medium flow direction extends in the direction of the drawn lines of fins 3. The sheet is designated in Fig. 2 with reference numeral 11.

Fig. 3a shows a sheet 21, the general structure of which corresponds with that of sheet 1 of Fig. 1. Sheet 21 is not however provided with fins 2, 3, but is provided instead with two perforations 22, 23. Into these perforations fit fins 24 which are arranged on a heat-conducting wall 25, for instance by welding or soldering. The fins as well as the wall can be manufactured from for instance copper. Fins designated

with 26 are likewise situated on the other side of the wall. The respective blocks of fins fit into perforations 22, 23. The heat-conducting wall part 25 is adhered sealingly to plate 21, for instance by glueing. The finally obtained structure has the same external structure as shown in Fig. 1a. The structure differs from that in Fig. 1a in that the plate or wall part 25 extends on the underside of sheet 1. It is of course necessary to take into account that wall part 25 must bend readily along hinge lines 6.

It is further noted in respect of Fig. 3b that fins 26 are shown with contour lines only for the sake of clarity. They are of course not visible in this perspective view.

Fig. 4 shows the interior 31, i.e. without a housing or casing, of a dew point cooler with the fins omitted. A number of units 32, comparable to the unit of Fig. 1c, are placed in a base 33. As described briefly above, water can be drained via water outlets 34 via an opening 35 in base 33.
Fig. 5a and 5b each show a dew point cooler 41 with two units 42, 43. As shown in Fig. 5b, a primary medium flow 44 is admitted to the inside from the one side. On the other side a part of this primary flow, designated 45, exits to the outside. Another part 46 is reversed as partial flow and passes over the watered fins 47. The thus wetted secondary airflow 48 is deflected upward by deflection dams 49 and leaves unit 41 from the top side.

Fig. 6 shows a base in the form of a tray 51 in which a number of units 52 are disposed. Use is also made in this embodiment of deflection dams 53. Fins are not drawn. The openings between funnels 54 give access to the bottom of the tray for water drainage via outlet opening 55.

Fig. 7 shows a structure related to that of Fig. 4. Units 61 have a differently moulded drainage provision.

Fig. 8 shows two units 71 based on the principles elucidated with reference to Fig. 3a and 3b. A copper plate or foil 72 bears on both sides fins which are ordered in respective blocks 73, 74, 75. Identical fins are situated on the non-visible side. These fit as according to an arrow 176 through respective openings 76, 77, 78 in preformed

sheet 79. Similarly to the structure shown in Fig. 1c, the walls are folded in the upper hinge zone into a mutually parallel relation, whereafter the free edges 10 are adhered to each other. At variance with the structure of Fig. 1, use is made in this embodiment of a single hinge line 80 which is embodied as a score with a substantially rigid zone on either side such that, also due to the correspondingly formed co-acting lower wall parts 83, 84, the final mutual distance of walls 81, 82 corresponds with the chosen distance.

This distance can for instance be chosen such that the fins press against each other. By means of a suitable pressing construction it is possible to hereby achieve that units 71 (of which there can be more than two) form a mechanically substantially rigid packet. The fins thus make an essential contribution toward the mechanical strength of the finally obtained heat exchanger.

Fig. 9 shows an alternative embodiment of the heat exchanger according to the invention. Heat exchanger 90 comprises two sheets 91, 92 which are each folded in the form of respective rectangular wave shapes of identical pitch or wavelength. Sheets 91, 92 are positioned mutually interlaced with a relative longitudinal orientation of 90°. The manifolds necessary for feeding and discharging the primary and secondary medium flow are omitted from this schematic drawing. Heat exchanger 90 comprises fins, all designated with 93.

As in the embodiment of Fig. 3, in the embodiment of Fig. 9 the heat exchanger 90 can advantageously be embodied such that fins 93 are in heat-exchanging contact with each other via respective holes in sheets 91, 92, for instance via heat-conducting carrier plates 94. This avoids the heat resistance via the two sheets 91, 92 becoming disturbingly manifest at the location of the fins. Fins 93 and carrier plates 94 must in that case be in the most direct possible thermal contact with each other, for instance by means of a heat-conducting glue layer (for instance a thin pressure-sensitive or thermally activated plastic glue layer), a welding operation, a soldering operation, a mechanical coupling or the like.

Fig. 10a shows an opened mould consisting of a lower mould part 101 and an upper mould part 102 which corresponds therewith and which can be closed as according

to arrow 103 to cause plastic cold deformation of an aluminium plate 104, which is covered on both sides with a glue layer activated by heat and pressure. For use with aluminium, a PVC/polyacrylate based adhesive has been found to be suitable. This may be provided with a thickness of about 3 microns, preferably in combination with a PVC primer in the form of a heat-seal lacquer of about 2 micron thickness.

Fig. 10b shows that a strip of fins 106, 107 is positioned from both sides on the thus formed, moulded heat-exchanging wall 105 and then pressed on as according to arrows 108, 109 respectively. It is noted that the lower surfaces 120 of fins 107 and the upper surfaces 110 of fins 106 are preferably also provided with a glue layer activated by heat and pressure, which may be of the same type as that applied to the plate 104. Alternatively, it may be selected to have a higher melting temperature thereby preventing loosening of the fins during heat-sealing of the plate 104.

Fig. 10c shows wall 105 with the strips of fins 106, 107 arranged thereon.

Fig. 10d shows the manner in which a number of identical heat-exchanging walls 105 with fins 106, 107 arranged thereon can be coupled to each other to form the interior of a heat exchanger, which must later also be placed in a suitable housing, having inlets and outlets for the primary and the secondary medium, as well as associated manifolds, whereby said inlets and outlets can be coupled in the correct manner to the diverse channels in heat exchanger unit 111 of Fig. 10d. In Fig. 10d it is also noted how the two sets of fins 107 support against one another to provide a reinforced structure. A foil 121 may be provided between the fins 107 in Fig. 10d to increase the stability of the structure.

Fig. 11 shows an alternative in which an adhesive foil 112 is placed between two finished walls with fins, whereafter, by suitably pressing together the edge zones 113 with foil 112 therebetween as according to arrows 114 and by pressing the fins 107 against each other with foil 112 therebetween as according to arrows 115, a mechanically very strong structure is created which, owing to the tensively strong connection between walls 105 via adhesive foil 112, is able to withstand an increased internal pressure in the relevant heat-exchanging medium. A very effective manner of causing the adhesive foil 112 to melt under some pressure is to feed hot air

through the space occupied by fins 107. The desired softening and, after cooling, the desired adhesion is hereby realized in a short time. The adhesive foil layer 112 is manufactured from a plastic having a relatively low softening and melting point compared with that of the heat-seal adhesive on the fins.

While Figs.10a – 11 show flow channels being formed by joining two like laminate portions. It is noted that a construction by folding a single laminate e.g. provided with fins on both surfaces may also be achieved in a similar manner to that shown in Figs. 1-3.

Fig. 12 shows in greater detail a strip of fins 107, for instance of copper or aluminium, as shown schematically in earlier figures. The strip can for instance be embodied as a laminate consisting of a base layer of copper or aluminium, a layer of primer applied thereto and an anti-corrosive adhesive layer applied thereover, activated by heat and pressure for coupling of the strip of fins 107 to a wall 105. The laminate is also provided with a liquid retaining layer 204 on an upper surface thereof.

The liquid retaining layer 204 is formed from a fibrous non-woven material. Although reference is made to a liquid retaining layer, it is clearly understood that the layer is in fact a liquid retaining and releasing layer. The layer 204 is schematically illustrated to have a very open structure such that the metal laminate can be clearly seen through the spaces between the fibres of the layer 204. An exemplary material for forming the water retaining layer is a 20g/m2 polyester/viscose 50/50 blend, available from Lantor B.V. in The Netherlands. Another exemplary material is a 30g/m2 polyamide coated polyester fibre available under the name ColbackTM from Colbond N.V. in The Netherlands. Other materials having similar properties including synthetic and natural fibres such as wool may also be used. Where necessary, the liquid retaining layer may be coated or otherwise treated to provide anti bacterial or other anti fouling properties.

The liquid retaining layer 204 may be adhesively attached to the metal layer over the entire area of the laminate 1. For use with aluminium and Lantor fibres as mentioned above, a 2 micron layer of two-component polyurethane adhesive has been found to

provide excellent results. When present as such a thin layer, its effect on heat transfer is negligible. Other liquid retaining layers such as Portland cement as mentioned above may also be used.

According to Fig. 12 The strip comprises individual fins 216 each provided with louvres 218 in the form of elongate slots penetrating through the laminate (only the louvres on the first fin are shown). The louvres 218 are arranged in groups. A first group 220 serves to direct flow into the surface, while a second group 222 directs flow out of the surface. Thus, some of the air flowing along the fins 216 in the direction of arrow A will be directed through the laminate towards the lower second surface. Air following the direction of arrow B will be directed outwardly by the second group of louvres. In this way, the air alternately flows over the first surface, where it can receive moisture by evaporation from the liquid retaining layer, followed by the second surface where it can receive direct thermal energy to raise its temperature.

In addition to their function in directing flow between the surfaces of the fins 216, louvres 218 also serve to break up the boundary layers that may develop as air flows along the surfaces. Other break up elements may be provided in addition or instead of the louvres 218. Furthermore, while the fins 216 of Fig. 12 are straight, curvilinear or zig-zag fins may also be produced. It is believed that such fin shapes are advantageous in breaking up the boundary layers that develop in flow along the fins, since each time the fin changes direction, turbulent flow is re-established. Various cross-sectional shapes are also possible for the fins, including corrugations of square, trapezoidal, rectangular, bell and sine wave shapes. In particular, it is noted that the base or trough 208 of the fin should preferably be as flat as possible with sharp corners in order to maximise the area of heat transfer to the plate 105.

In addition to louvres 218, fins 216 are provided with conduction bridges 224. These bridges 224 are in the form of cuts through the laminate over substantially the whole height of the fin 216. They serve to prevent unwanted transport of heat along the fins 216 in the direction of the air flow.

The strip of fins 107 is preferably formed using standard corrugation techniques. An appropriate width roll of prepared laminate may be fed through a pair of corrugated rollers which can form the fins 216, louvres 218 and heat bridges 224 in a single pass. The resulting product may then be cut into suitably sized strips of fins 107 for further processing.

Finally, Fig. 13 shows a heat-exchanging wall 116 formed of a laminate according to the present invention, with relatively shallow stiffening profiles 117 on both short sides, in addition to bent edges 118 with end flanges 119, which bent edges 118 can act as reflection dams. It is noted in this respect that it is unnecessary in most applications to make use of the smooth rounded form of deflector dams as shown for instance in Fig. 1a. The flows of the media are generally steady such that there need be no fear of undesired losses.

The heat-exchanging wall 116 of Fig. 13 is symmetrical. This may not be essential in all circumstances.

While the above examples illustrate preferred embodiments of the present invention it is noted that various other arrangements may also be considered which fall within the spirit and scope of the present invention as defined by the appended claims.